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WATER QUALITY OF PENCIL LAKE IN RELATION TO SHORELINE DEVELOPMENT

PETERBOROUGH COUNTY
CAVENDISH TOWNSHIP

October 1977

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WATER QUALITY
OF PENCIL LAKE
IN RELATION TO
SHORELINE DEVELOPMENT

County of Peterborough

Cavendish Township

Field Survey - 1976
Report - 1977

Report Prepared By

Technical Support Section

Central Region

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INTRODUCTION

During the summer of 1975 a draft proposal for a cottage subdivision was circulated by the Ministry of Housing to the Central Region of the Ministry of the Environment for comments. Minimal information on water quality in the lake was available at the time. From a preliminary investigation done in the fall of 1975, it was decided to carry out a water quality survey of the lake during the ice free period of 1976.

The purposes of the survey were:

1. to outline the existing water quality status of Pencil Lake
2. to assess the effects of the proposed additional development on the water quality status of the Lake.

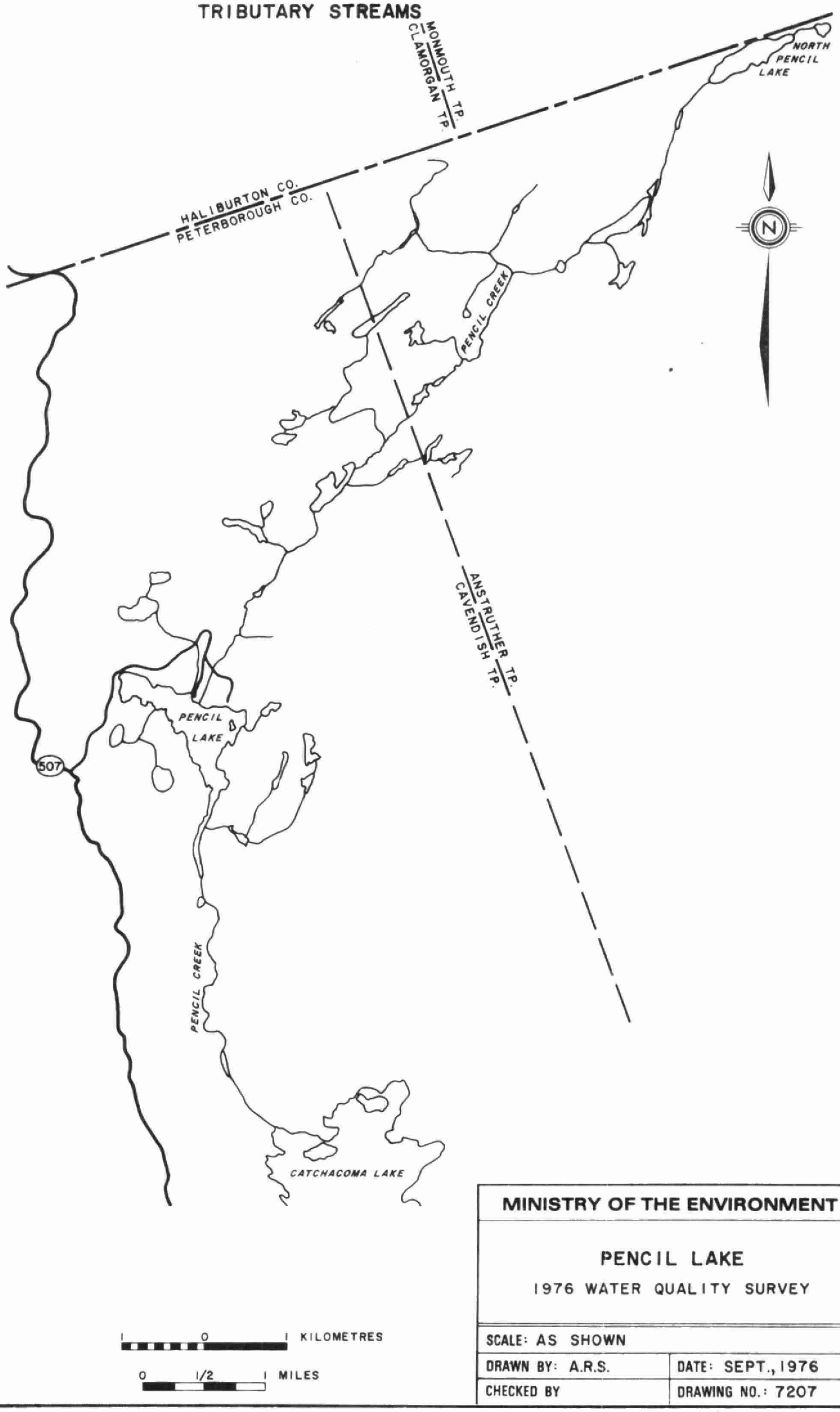
DESCRIPTION OF THE STUDY AREA

Pencil Lake is located approximately 64 kilometers north of the City of Peterborough in Cavendish Township (lots 19 to 22, Concession 12 to 14), Peterborough County.

The Lake and its immediate drainage basin are located in the Pre-Cambrian Shield geological region. The physiography of the area is hilly with frequent bedrock outcroppings. Overburden is generally thin with some pockets of greater than 3 meters depth above bedrock. The soil found in the area is a coarse sandy till. The watershed is largely forested with mixed deciduous and coniferous forest.

The main inflow to the Lake is Pencil Creek, entering from the north east (Figure 1). There are four other small inlets but

FIGURE 1 - GEOGRAPHIC LOCATION OF PENCIL LAKE SHOWING TRIBUTARY STREAMS



MINISTRY OF THE ENVIRONMENT

PENCIL LAKE

1976 WATER QUALITY SURVEY

SCALE: AS SHOWN

DRAWN BY: A.R.S.
DATE: SEPT., 1976

CHECKED BY
DRAWING NO.: 7207

they were not of sufficient flow to be sampled during the survey. Flow into Pencil Lake is naturally controlled. Drainage from the lake is via Pencil Creek which flows south to Catchacoma Lake and eventually meets the Trent Canal system via the Mississauga River.

The following are some morphometric data on the lake and its watershed.

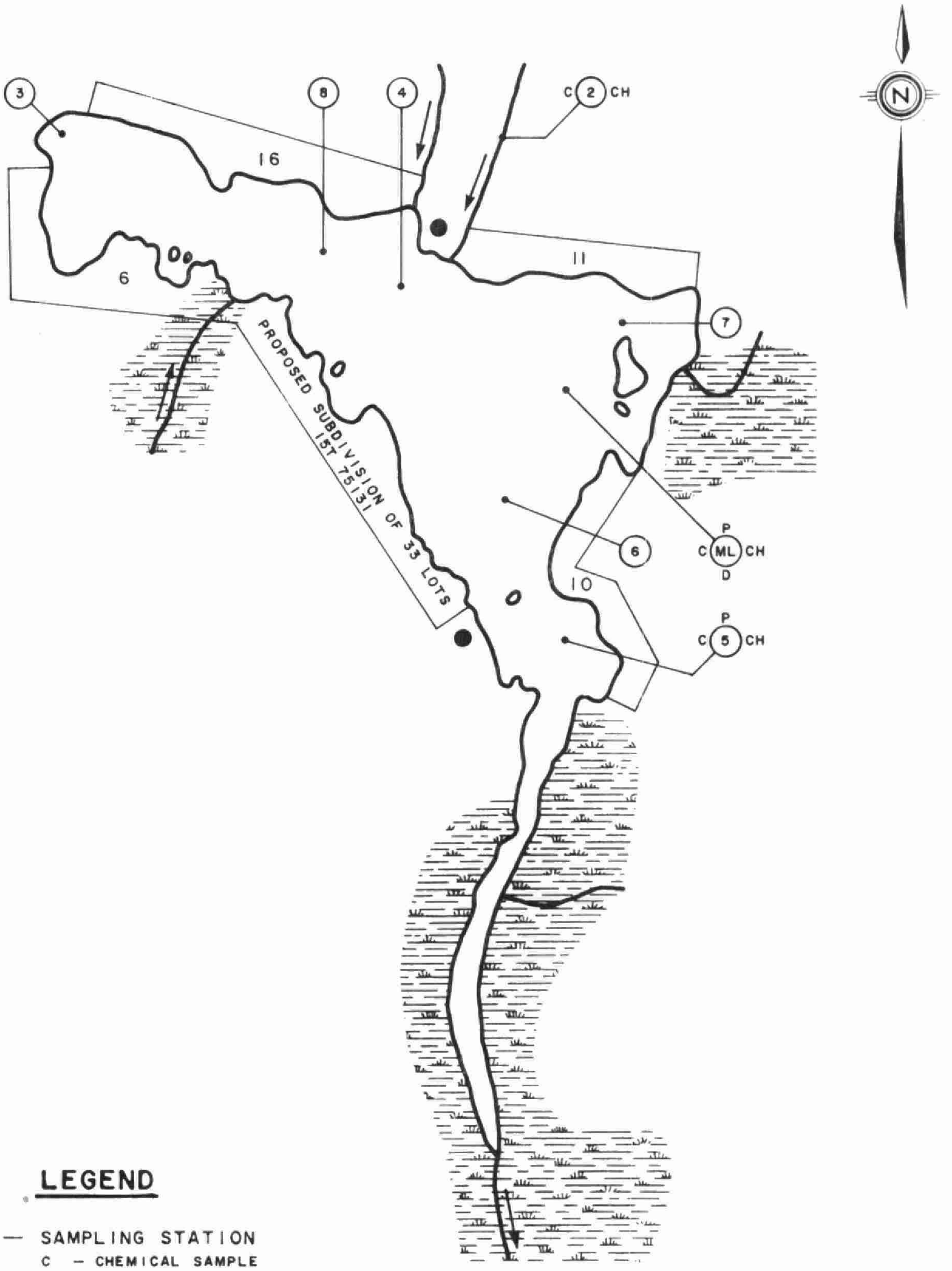
lake surface area (Ao)	765,700 m^2
maximum depth (Z max)	23 m
mean depth ($\bar{Z}$)	8.4 m
lake volume (V)	6.42×10^6 m^3
drainage area (Ad)	27.35 Km^2

Pencil Lake has several recreational uses including swimming, water skiing and boating. There were about 44 cottages on the lake during the survey. Several cottagers use the lake as a source of water supply. According to the Ministry of Natural Resources, small mouth bass, large mouth bass and speckled trout are found in the Lake.

SURVEY PROCEDURES

Two lake stations (ML & 5 - Figure 2) and a station on Pencil Creek (2 - Figure 2) were sampled for a variety of water quality parameters. Stations ML and 2 were sampled on nine occasions at approximately three week intervals between May 4 and October 26, 1976, while station 5 was sampled on only three occasions. In addition to this regular water-quality sampling, a total of seven sediment samples (Figure 2) were obtained during the survey for benthic-invertebrate analyses.

FIGURE 2 - SAMPLING STATION LOCATIONS, PENCIL LAKE



LEGEND

P
C 8 CH — SAMPLING STATION
D

C – CHEMICAL SAMPLE
P – PROFILE
CH – CHLOROPHYLL SAMPLE
D – DEPTH STATION
BIOLOGICAL SAMPLES TAKEN
AT ALL STATIONS

16 ● — SHORELINE DEVELOPMENT

0 .5 KILOMETRES

0 1/8 1/4 MILES

MINISTRY OF THE ENVIRONMENT

PENCIL LAKE
1976 WATER QUALITY SURVEY

SCALE: AS SHOWN	
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CHECKED BY:	DRAWING Nº: 7195

The following activities were normally conducted during each visit to the lake.

A. Lake temperature profiles were obtained using a calibrated marine thermometer (Hydrolab Corp. model FT-3M). Temperature at station 2 was taken with a standard laboratory thermometer.

Dissolved oxygen concentrations in the lake profile and at station 2 were determined using the azide modification of the Winkler method.

B. Water clarity was measured using a Secchi disc (30 cm. diameter disc divided into alternate black and white quadrants).

C. Samples for general water chemistry, chlorophyll _a_ and phytoplankton were obtained as composites through the euphotic zone (calculated as twice the Secchi disc depth). This was accomplished by lowering and raising a 1 litre bottle through the predetermined depth of the euphotic zone at a rate that allowed complete filling just as the bottle was lifted out of the water. The chlorophyll _a_ samples were preserved with 1 ml of a 2% suspension of magnesium carbonate and delivered to the MOE lab within 24 hours. Phytoplankton samples were preserved with Lugol's solution.

D. Samples for general water chemistry were taken 1 meter off the bottom using a Kemmerer sampler.

E. A sample of benthic macroinvertebrates was taken from various stations (one sample per visit for seven of nine visits) using an Ekman dredge (9 x 9 inches or 23 x 23 cm) and screen bucket with about 0.65 mm mesh aperture. Invertebrates were "picked" from the debris using enamel trays and forceps and preserved in 5% buffered formalin.

Chemical analyses performed on each water sample included total and soluble phosphorus, free ammonia, total kjeldahl nitrogen, nitrite, nitrate, total iron, alkalinity, hardness, conductivity, pH, colour and chlorides. Because of the low concentrations found, duplicate analyses were performed on all phosphorus and nitrogen determinations for each sample run. On September 7, 1976, additional samples were taken and analysed for major anions and cations. All analyses of water samples were performed at the MOE lab using standard laboratory methods of the Water Quality Section, Laboratory Branch, M.O.E.

Phytoplankton samples were identified and listed by staff of the Limnology and Toxicity Section, Water Resources Branch. Dominant forms were indicated in results.

Benthic invertebrates were identified and enumerated by staff of the Technical Support Section, M.O.E. Central Region. Identification was carried to the family level according to Edmondson (1959).

SURVEY RESULTS

All physical and chemical data are outlined in Appendicies 1 to 5. Station ML was considered to be representative of the physical and chemical quality of the Lake as a whole.

Temperature and Light

Thermal stratification of Pencil Lake occurred during the survey. A thermocline (zone of rapid temperature decline) was noted at the end of May and varied in depth and thickness through the summer (see Appendix 5). Bottom water temperatures were generally just above $4^{o}C$ throughout the survey while surface water temperature reached a maximum of $23.4^{o}C$ in June.

Pencil Lake water had a brown colouration with an apparent colour of 30 Hazen units. The colouration was probably caused by the presence of natural tanins and humic acids in the inflowing surface water (average colour in Pencil Creek, Station 2, was 63 Hazen units).

Lake water clarity, as measured by Secchi disc, was moderate with a mean depth of 3.7 meters at Station ML. Very little fluctuation in water clarity was noted over the survey (range 3.0 to 4.4 meters). Water clarity was undoubtedly affected by the brown colouration of the water as well as by phytoplankton. Unfortunately there is no known relationship between the amount of colour and the Secchi disc depth that would allow a correction for the reduction in Secchi disc depths. The euphotic zone (deliniated by twice the Secchi disc depth) generally extended to the thermocline. Oligotrophic, nutrient poor lakes generally have Secchi disc depths of 5 or more meters. Pencil Lake can be considered in the mesctrophic category in this regard.

Basic Water Chemistry

Surface water alkalinity, hardness and conductivity values of 36 mg/l as $CaCO_3$, 48 mg/l as $CaCO_3$ and 97 uhos/cm^3 respectively indicated that Pencil Lake had relatively soft water. This condition is common in lakes and streams located on the Precambrian Shield.

Figure 3 shows the relative importance of the major cations and anions in Pencil Lake water. The most important cation was calcium while the predominant anion was bicarbonate. Sodium and chloride on the other hand, were not significant as they are in watersheds affected by extensive development.

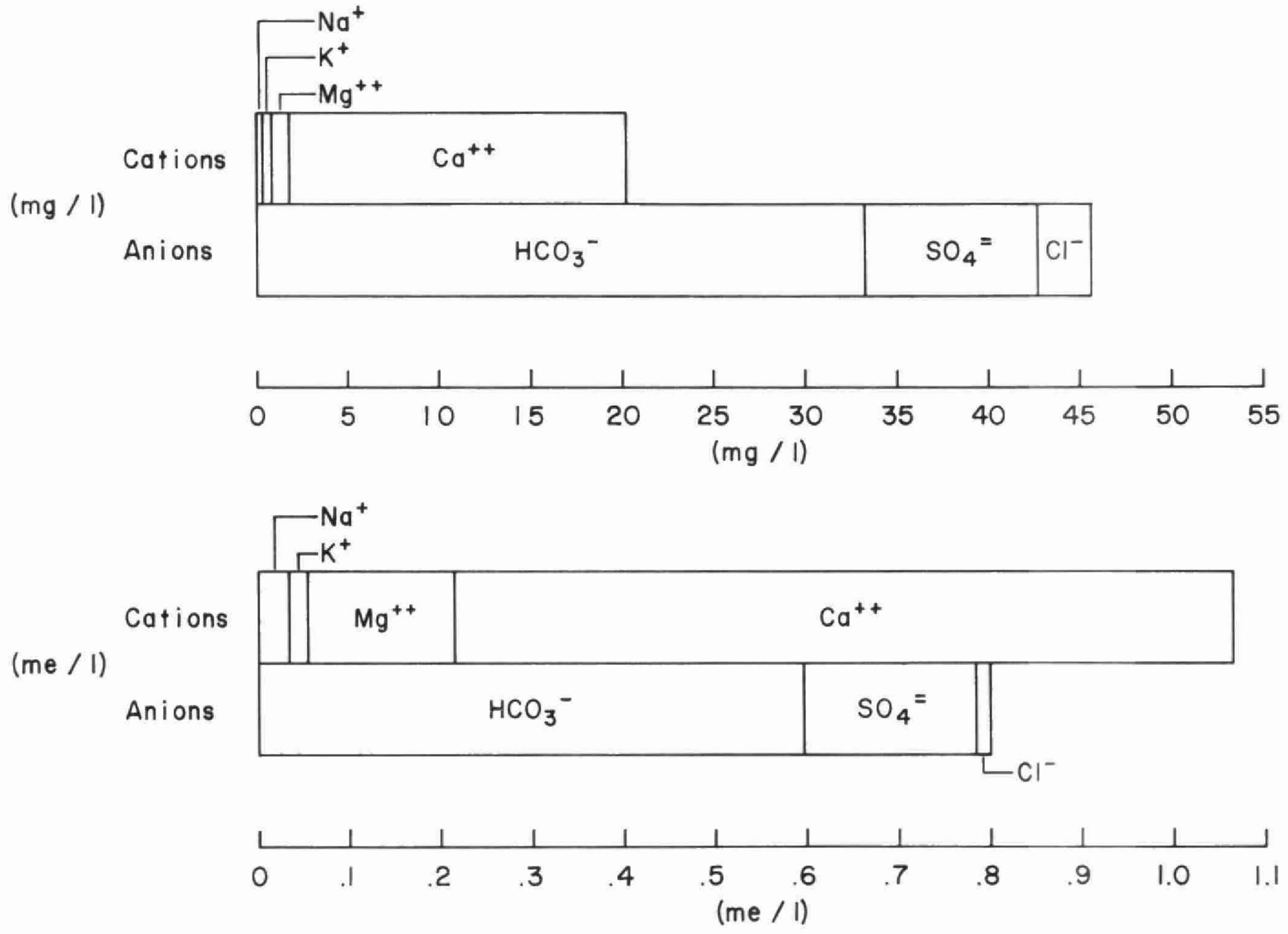

FIGURE 3 - MAJOR CATIONS AND ANIONS SAMPLED FROM MID-LAKE STATION 7/9/76

The Lake was slightly basic with an average pH of 7.68 pH units in the surface waters and 7.11 pH units in the bottom waters.

Dissolved Oxygen

The dissolved oxygen profile in the Lake was clinograde in nature. The epilimnion (water above the thermocline) was well oxygenated during the survey with dissolved oxygen concentrations in excess of 80% saturation. In the hypolimnion (water below the thermocline) the dissolved oxygen concentration varied over the survey. A minimum of 3 percent saturation was reached on two occasions (August 10 and October 26) at 1 meter off the lake bottom. By September 29 the oxygen concentration had declined to less than 30 percent saturation through most of the hypoliminion.

Nutrients

Phosphorous has been identified as the key plant nutrient that limits growth in most lakes. Concentrations of total phosphorus in Pencil Lake were low, averaging 8.5 ug/l in the surface waters, and fluctuated very little over the survey (range 6.5 to 10.0 ug/l). This concentration was comparable to that measured in other oligotrophic lakes in the Precambrian Shield such as Lake Rosseau (8 ug/l) and Skeleton Lake (9 ug/l).

The bottom water total phosphorus concentration also averaged 8.5 ug/l. Even at periods of low dissolved oxygen concentration phosphorus values were not elevated in the bottom waters. This indicated that organic matter was not accumulating in the hypolimnion.

Nitrogen is another important plant nutrient in lakes. The total kjeldahl nitrogen concentration was similar in surface and bottom waters (0.340 mgN/l and 0.320 mgN/l respectively) indicating again that no accumulation of organic matter was taking place in the bottom waters.

Inorganic nitrogen concentrations in the surface waters of the lake were moderately low. Values for nitrite, nitrate and ammonia nitrogen in surface waters were 0.002 mgN/l, 0.030 mgN/l and 0.010 mgN/l respectively. Slightly higher concentrations of nitrate and ammonia nitrogen were found in the bottom waters (0.170 mgN/l and 0.031 mgN/l respectively). Two peaks in ammonia concentration in the bottom waters on August 10 and October 26 corresponded with the minimum bottom water dissolved oxygen concentrations.

Total iron concentration in surface waters averaged 0.064 mgFe/l while a slightly higher concentration of 0.153 mgFe/l was found in the bottom waters.

Chlorophyll a

Chlorophyll a is a pigment present in all phytoplankton (suspended algae). It's concentration indicates the density of phytoplankton in the water column. The mean euphotic zone concentration of chlorophyll a in Pencil Lake was 2.3 ug/l, ranging from 1.1 to 5.1 ug/l. A relationship between chlorophyll a and Secchi disc depth has been defined by MOE scientists that allows a comparison of the enrichment status of lakes. Figure 4 shows the position of Pencil Lake in the relationship to be similar to Cameron Lake, a nutrient poor lake of good water quality. In general, oligotrophic lakes have chlorophyll a concentrations less than 2.0 ug/l. With respect to chlorophyll a, Pencil Lake must be considered bordering on oligotraphic status.

Phytoplankton

The phytoplankton most commonly found through the survey was an

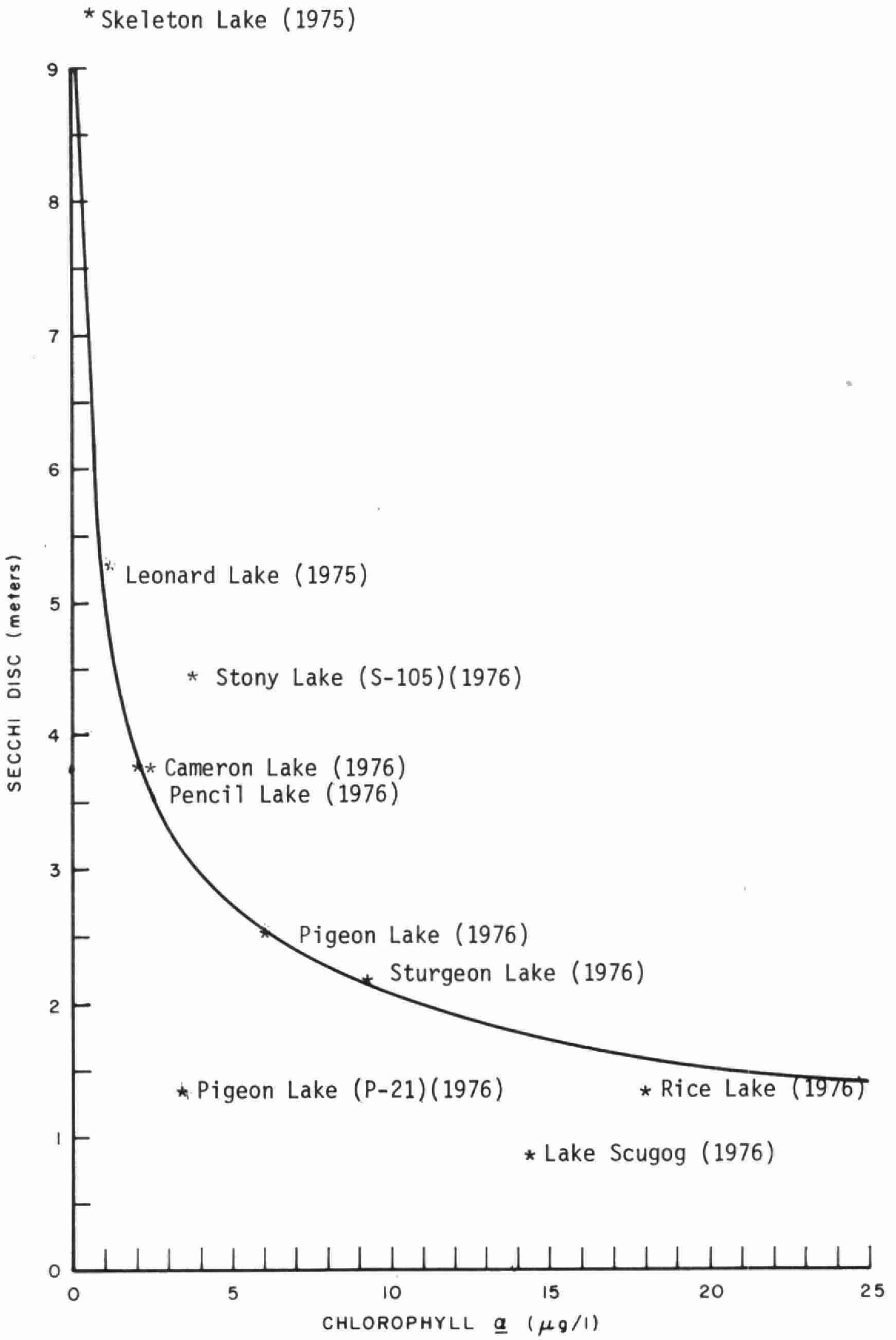

Figure 4 Secchi Disc - Chlorophyll a Relationship in Pencil Lake compared with some other Lakes in Southern Ontario

unidentified chrysomonad and Rhodomonas (see Appendix 6). The blue green algae Aphanothece became common in August and October.

Aphanothece is normally associated with phytoplankton communities in nutrient poor lakes. Another blue-green algae, Aphanizomenon, was found in Pencil Lake only during September. This algae is normally not found in nutrient poor lakes. Should nutrient concentrations significantly increase in the lake, growth conditions for this algae would improve, perhaps resulting in undesirable "blooms" of Aphanizomenon in the lake.

In summary, the composition of phytoplankton in Pencil Lake indicated conditions bordering oligotrophy but nutrient sources to the lake should be carefully controlled to avoid undesireable phytoplankton growths.

Benthic Invertebrates

Two areas of the Lake bottom were sampled for benthic macroinvertebrates during the survey, the shallow or littoral zone (represented by stations 3, 5 and 7) and the deep or profundal zone (represented by stations ML, 4, 6 and 8). Results are illustrated in Appendix 7.

The littoral zone was characterized by a relatively diverse habitat (sand, gravel, mud, organic matter). Chironomidae or midge larvae dominated the community but mayflies, helgramites and caddisflies were also present.

The profundal zone was very uniform with sediment at all four stations consisting of gyttja (a greyish brown, highly organic material with a consistency similar to pudding). The community here consisted largely of chaoboridae and chironomidae. Both of these organisms are known to thrive in an environment of low oxygen concentration. Densities of the organisms are comparable to those of other nutrient poor lakes. Conspicuously absent from this zone are oligochaetes (especially tubificidae) that are associated with more enriched lake sediments.

WATER QUALITY STATUS

The physical, chemical and biological water quality of Pencil Lake is good. Considering the preceeding discussion of the various indications of trophic status, Pencil Lake must be placed on the border between oligotrophy and mesotrophy. Although the water quality is good at present, significant increases in the phosphorus loading to the lake could have the following effects.

1. undesirabile algae (e.g. Aphanizomenon), favoured by increased phosphorus concentration, may increase to nuisance proportions.

2. the severity of dissolved oxygen depletion in the hypolimnion may increase, accompanied by nutrient accumulation and added algae problems at spring overturn.

PHOSPHORUS BUDGET AND DEVELOPMENT

To estimate the significance of various sources of phosphorus to the water quality of Pencil Lake, a budget was calculated. The only available methodology for making such a calculation and for predicting the water quality effects of further development on lakes of the Precambrian Shield is outlined in the MOE publication by Dr. P. Dillon "A Manual For Calculating The Capacity of A Lake For Development", March 1975. Calculations were made using the model, with modifications, as outlined in Appendix 8.

The separation of phosphorus sources to Pencil Lake using the model was as follows:

Supply from land drainage	150 kg/yr.
Supply from precipitation	38 kg/yr
Supply from existing cottages	18 kg/yr
Total Supply	206 kg/yr

Predictions of existing water quality conditions in the lake using the model were compared with measurements taken during the survey.

	Spring Phosphorus (mg/m^3)	Chlorophyll a (mg/m^3)	Secchi Disc (m)
Predicted	9.0	1.75	4.1
Measured	10.5	2.3	3.7

The model was in reasonable agreement with the actual values. However, the prediction of water quality was not considered accurate enough to be used as a base for predictions of future development effects on water quality.

To assess the water quality effects of further development on Pencil Lake, two development options were considered.

1. 33 additional cottages (the number indicated in proposed subdivision 15T-75131)
2. 50 additional cottages

The following table shows the predicted degree of change using Dillon's model for each development option applied to the measured water quality parameter.

	Spring Phosphorus (mg/m^3)	Chlorophyll a (mg/m^3)	Secchi Disc (m)
measured	10.5	2.3	3.7
33 more cottages	11.2	2.51	3.6
50 more cottages	11.6	2.64	3.5

Very little change in water quality for those parameters listed is expected if the proposed subdivision of 33 cottages is approved and built. A 15 percent increase in chlorophyll a concentration and a decrease of only 5 percent in Secchi disc depths are expected with 50 more cottages on the Pencil Lake shoreline. With the present lot size requirements and the physical constraints of the lake shoreline (i.e. low, marsh areas) it is unlikely that more than 50 additional shoreline lots could be positioned on the lake.

With carefully controlled artificial phosphorus inputs and no significant change in the forest cover of the watershed, water quality considerations may not be the major limiting factor for further shoreline development on Pencil Lake. Suitable shoreline space may become the limiting factor before water quality constraints become important.

SUMMARY RECOMMENDATIONS AND CONCLUSIONS

1. A water quality survey of Pencil Lake was undertaken to define the existing water quality status of the lake and to predict the effects of further development on the lake. The survey was carried out between May 4 and October 26, 1976.

2. Pencil Lake was found to have good water quality with a trophic status bordering oligotrophic. Mean total phosphorus concentration, chlorophyll a concentration and Secchi disc depth measured were 8.5 ug/l, 2.3 ug/l and 3.7 meters respectively.

3. The lake can be termed "sensitive" with respect to dissolved oxygen concentration which approaches anaerobic conditions in the lower hypolimnion just prior to fall overturn. A significant increase in phosphorus loading to the lake would

cause more severe dissolved oxygen depletion which in turn would encourage phytoplankton growths in the lake to reach nuisance proportions.

4 It was estimated that only a small change in the water quality of Pencil Lake would occur as a result of the additional phosphorus loading to the lake from 33 more cottages. However, because of the sensitive nature of the lake, it is recommended that a 100 foot set-back of septic tank and tile bed systems be required in the proposed lots (except lots 1 and 14) and that staff of the Ministry of Health designate the position of the tile beds within each lot before approval of the system is given. Moreover, any fill material used for the installation of the tile field systems should be of a reasonably fine nature to encourage the retention of waste materials such as phosphorus.

5. Cottagers are asked to ensure that the existing disposal systems meet the current requirements of the Ministry of the Environment.

6. With careful control of artificial phosphorus inputs to Pencil Lake and with no significant change in the forest cover of the watershed, water quality considerations may not be the major limiting factor for further shoreline development. Suitable shoreline space may become the limiting factor before water quality constraints.

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Appendix 1. Results for Euphotic Zone Samples at Station ML

Date	Secchi disc-m.	Chlor. a/b-ug/l	Alk.-mg/l	T.Iron-mg/l	Hard-mg/l	T.Phos. ug/l	S. Phos. ug/l	TKN-mg/l	NO_2-mg/l	NO_3-mg/l	NH_3-mg/l	Cl-mg/l	Cond.-umhos/cm^3	Colour-Hazen units	PH
May 4/76	3.0	2.1/1.3	34	0.10	44	10.5	<1	0.290	0.003	0.087	0.002	0.7	95	30	7.52
May 26/76	4.2	1.6/1.4	35	0.09	43	9.0	<1	0.380	0.003	0.077	0.013	0.7	85	30	7.61
June 10/76	3.1	2.1/0.6	37	0.06	56	7.0	2	0.375	0.002	0.008	0.010	0.7	95	40	7.82
June 30/76	3.9	3.2/2.0	25	0.06	46	6.6	1	0.365	0.002	0.021	0.013	0.6	96	30	7.72
July 21/76	4.4	1.2/0.2	39	0.08	48	8.5	<1	0.360	0.002	0.007	0.012	0.6	98	30	
Aug. 10/76	4.3	5.1/1.9	40	0.05	48	7.0	<1	0.350	0.002	0.016	0.009	0.6	99	20	7.69
Sept. 7/76	4.1	2.6/1.9	38	0.05	51	9.5	2	0.290	0.001	0.009	0.015	0.7	100	30	7.66
Sept.29/76	3.4	1.1/0.1	39	0.04	48	9.0	1	0.350	0.001	<0.005	0.005	0.4	106	30	7.71
Oct. 26/76	3.2	1.3/0.7	38	0.05	51	9.5	1	0.290	0.002	0.038	0.010	0.5	100	30	7.65
MAX.	4.4	5.1/2.0	40	0.10	56	10.0	2	0.380	0.003	0.087	0.015	0.70	106	40	7.82
MIN.	3.0	1.1/0.1	25	0.04	43	6.5	1	0.290	0.001	0.005	0.002	0.40	85	20	7.52
MEAN	3.7	2.3/1.1	36	0.06	48	8.5	1	0.340	0.002	0.030	0.010	0.61	97	30	7.68

Appendix 2 Results for Samples Taken 1 m. off Bottom at Station ML

Date	Sample depth-m	Alk-mg/1	T.Iron-mg/1	Hard-mg/1	T.Phos.-mg/1	T.Phos.-ug/1	TKN-mg/1	NO$_2$-mg/1	NO$_3$-mg/1	NH$_3$-mg/1	Cl-mg/1	Cond.-umhos/cm^3	Colour-Hazen units	PH
May 4/76	21.0	43	0.14	54	6.0	2	0.340	0.002	0.188	0.016	0.7	115	20	7.07
May 26/76	22.0	45	0.09	51	5.0	<1	0.220	0.002	0.230	0.007	0.8	110	**	7.41
June 10/76	21.5	43	0.38	53	7.5	1	0.300	0.001	0.111	< .002	0.8	111	20	7.16
June 30/76	21.0	23	0.07	51	5.5	1	0.290	0.001	0.172	< .002	0.8	106	30	7.01
July 21/76	21.0	43	0.06	53	8.5	< 1	0.360	0.001	0.199	0.006	0.7	105	30	
Aug. 10/76	22.0	47	0.15	54	16.0	1	0.500	0.003	0.150	0.093	0.7	111	*	6.92
Sept. 7/76	21.0		0.11	54	9.5	2	0.270	0.002	0.213	0.004		107	30	
Sept.29/76	22.0	42	0.10	48	9 0	1	0.300	0.001	0.197	0.004	0.6	104	30	6.94
Oct. 26/76	22.0	46	0.28	56	9.5	3	0.305	0.006	0.072	0.148	0.6	110>	70	7.26
MAX.		47.0	0.38	56	16	3	0.5	0.006	0.230	0.148	8	115	70	7.41
MIN.		23.0	0.06	48	5	1	0.22	0.001	0.072	0.002	6	104	20	6.92
MEAN		41.5	0.15	52	8.5	1	0.3205	0.002	0.170	0.031	7	109	33	7.11

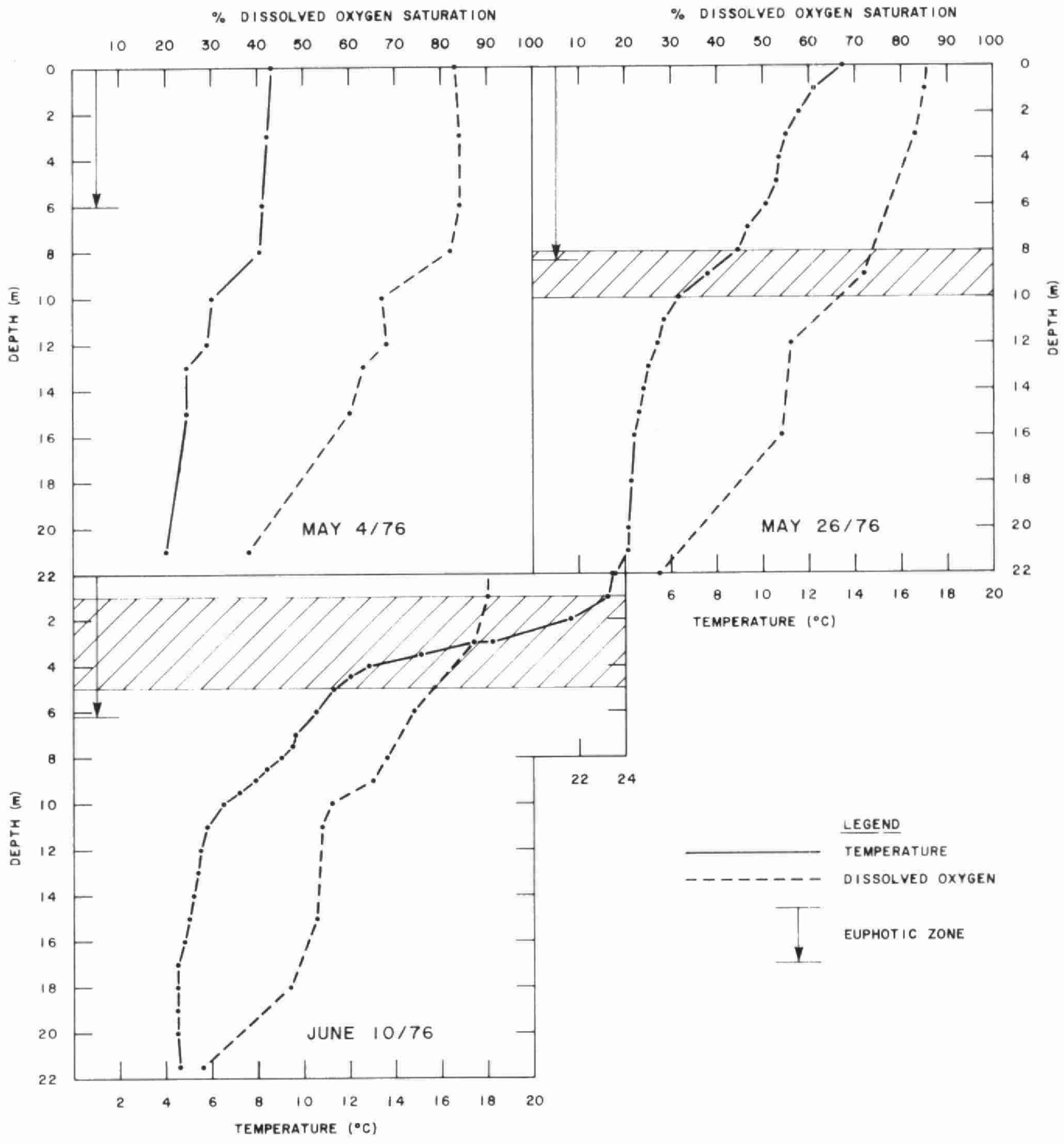
Appendix 3 Results for Euphotic Zone Samples at Station 5

Date	Station depth-m.	Secchi disc-m.	Chlor. a/b ug/l	Alk.-mg/l	T.Iron-mg/l	Hard.-mg/l	T.Phos.-ug/l	S.Phos.-ug/l	TKN-mg/l	NO_2-mg/l	NO_3-mg/l	NH_3-mg/l	Cl-mg/l	Cond.-umhos/cm^3	Colour-Hazen units	PH
July 21/76	5.5	3.4	1.7/0.6	40	0.38	49	8	4	0.33	0.002	<.005	0.019	0.6	99	30	
Sept. 7/76	5.0	3.6	3.0/2.8	39	0.06	51	12.5	2	0.27	0.001	<.005	0.005	0.7	98	30	8.01
Oct. 26/76	5.2	3.2	1.4/0.7	38	0.05	51	9	2	0.30	0.003	0.035	0.012	0.5	100	30	7.40

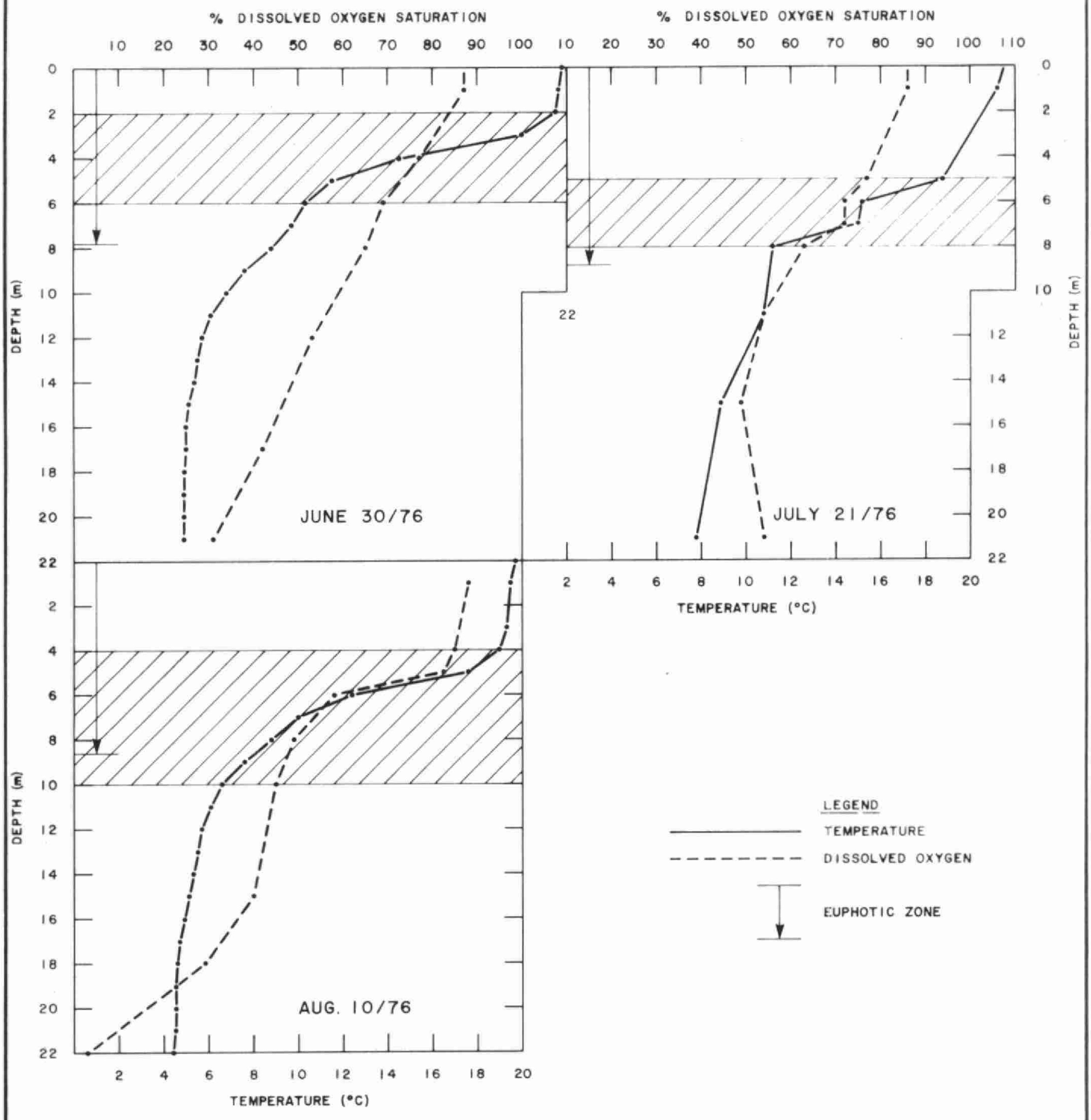
Date	Sample Depth (m)	Dissolved oxygen (mg/l)	Temp. (°C)
July 21/76	1.0 4.5	7.8 5.6	21.8 20.5
Sept. 7/76	1.0 4.0	9.4 8.7	19.5 18.4
Oct. 26/76	1.0 4.0	10.2 10.1	5.5 5.5

Appendix 4 Results for Samples Taken at Station 2

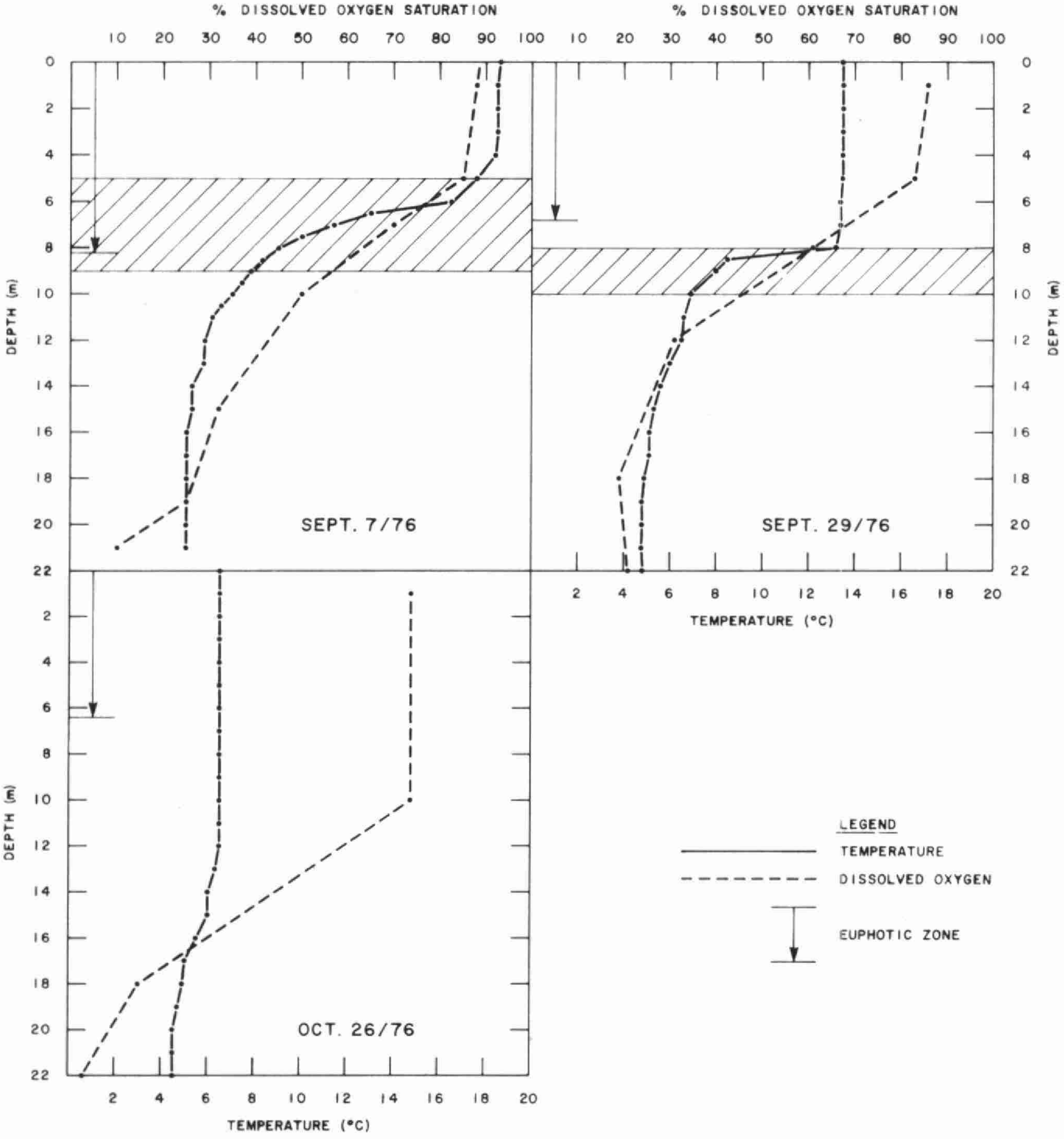
Date	Dissolved oxygen-mg/1	Temp. °C	BOD$_5$-mg/1	T.Phos-ug/1	S.Phos-ug/1	NH$_3$-mg/1	TKN-mg/1	NO$_2$-mg/1	NO$_3$-mg/1	T.Iron mg/1	Chlor a/b-ug/1	Cond. umhos/cm^3	PH	Alk-mg/1	Hard-mg/1	Cl-mg/1	Colour-Hazen units
May 4/76	10.1	11.4	0.6	10	1	0.010	0.43	0.004	<0.005	0.29	2.6/ .8	110	7.42			0.7	50
May 20/76	9.4	9.0	0.8	18	1	0.024	0.48	0.004	<0.005	0.27	2.8/ .8	90	7.36			0.5	70
May 26/76	8.2	13.4	0.6	12	1	0.014	0.45	0.003	<0.005	0.23	2.8/1.8	80	7.59			0.4	70
June 10/76	5.5	23.1	1.0	26	3		0.66	0.003	<0.005	1.60	1.9/0.4	125	7.36			0.8	>70
July 6/76	8.0	25.0		28	3	0.014	0.40	0.004	0.011	0.42	2.2/2.2	120	7.79			0.4	>70
July 21/76	5.3	21.8		18	2	0.022	0.61	0.003	< .005	0.46	1.6/0.4	152		75	81	0.4	70
Aug. 10/76	7.2	17.9		15	1	0.009	0.71	0.002	0.007	0.26	1.5/0.1	159	7.61	80	88	0.4	50
Sept. 7/76	7.0	22.5		16	3	0.017	0.56	0.002	<.005	0.34	2.2/2.0	150	7.70	67	79	0.5	70
Sept.29/76	9.2	11.5		13.5	2	0.007	0.55	0.003	<.005	0.20	1.1/0.5	121	7.52	58	63	0.5	60
Oct. 26/76	12.1	3.0		14	1	0.009	0.48	0.003	<.006	0.24	1.6/0.8	98	7.72	39	52	0.9	50
MAX	12.1	25.0	1.0	28	3	0.024	0.71	0.004	0.011	1.60	2.8/2.2	159	7.79	80	88	0.9	70
MIN.	5.3	3.0	0.6	10	1	0.007	0.40	0.002	0.005	0.20	1.1/ .1	80	7.36	39	52	0.4	50
MEAN	8.2	15.9	0.8	17.1	2	0.014	0.53	0.003	0.006	0.43	2.0 /1.0	121	7.56	64	73	0.5	63



APPENDIX 5 – DISSOLVED OXYGEN CONCENTRATION / TEMPERATURE PROFILES FOR PENCIL LAKE STATION ML.



APPENDIX 5 – DISSOLVED OXYGEN CONCENTRATION / TEMPERATURE PROFILES FOR PENCIL LAKE STATION ML.



APPENDIX 5 - DISSOLVED OXYGEN CONCENTRATION / TEMPERATURE PROFILES FOR PENCIL LAKE STATION ML.

Appendix 6 PENCIL LAKE Phytoplankton Results *

	MAY 4 1976	MAY 26 1976	JUNE 10/76	JUNE 30/76	JULY 21/76	AUG. 10/76	SEPT. 17/76	SEPT. 30/76	OCT. 26/76
Cyanophyceae									
Anabaena				+	+			+	
Aphanizomenon							+		
Aphanocapsa							+		
Aphanothece			+	4	4	1	+	2	1
Chroococcus					+	4	+		5
Coelosphaerium							+		
Gomphosphaeria			+	5	+	3	+	4	3
Microcystis					+				
Unidentified-bluegreen					+		+		
dinophyceae									
Gymnodinium				+	+			+	
Unidentified - dinophyceae									+
cryptophyceae									
Chroomanas			+						
Cryptomonas		3	+	+	3	+	+	+	
Katablepharis	+	+	4	+			+	+	
Rhodomonas	1	2	3	3	1	2	2	3	
chrysophyceae									
Bitrichia								+	
Chromulina	+			+	+			+	+
Chrysochromulina	+		+	+	+				+
Chupolykas	+								
Dinobryon		+	5	+		+	+	+	+
Epipyxis				+					
Kephyrian	+	+		+					

	MAY 4 1976	MAY 26 1976	JUNE 10/76	JUNE 30/76	JULY 21/76	AUG. 10/76	SEPT. 7/76	SEPT. 30/76	OCT. 26/76
chrysophyceae (cont'd)									
Mallomonas	+			+	+	+	+		+
Salpingoeca				+					
Synura					+			5	
Uroglena	+								
Uroglenopsis			2	2					
Unidentified - bananachrys				+					
Unidentified - chrysomonad	2	1	1	1	2	3	+	1	2
chlorophyceae									
Botryococcus								+	
Chlamydomonas	+		+				+		
Coelastrum			+						
Dictyosphaerium							3		
Gloeocystis			+		+		+		+
Gyromitus							+		
Monoraphidium							+		
Oocystis			+				+	+	
Paramastix	+								
Unidentified green	3	+	+	+	5	5	+	+	
bacillariophyceae									
Achnanthes	+								
Asterionella				+					
Gyclotella			+	+			+		+
Fragilaria			+		+			+	
Navicula						+			
Nitzschia								+	
Synedra	+				+				

*			
1.	most dominant	4.	4th most dominant
2.	2nd most dominant	5.	5th most dominant
3.	3rd most dominant	+	present

Appendix 7 Pencil Lake Benthic Invertebrate Results *

Major Group (common name)	Family	Shallow Stations			Deep Stations			
		Sta 3 4.5m May 26	Sta 5 5 m Jul.20	Sta 7 4 m Aug 10	Sta ML 22m May 4	Sta 4 15 m Jun.10	Sta 6 20 m Jul.20	Sta 8 19.5 Sep.9
Oligochaeta (worms)	unidentified						38	
Amphipoda (Scuds)	Talitridae			38				
Acari (water mites)	unidentified		19					
Ephemeroptera (mayflies)	Caenidae			38				
	Ephemeridae	38		19				
Anisoptera (dragon flies)	Macromiidae			38				
Neuroptera (Helgramites)	Sialidae	38						
Trichoptera (caddis flies)	Helicopsychidae			19				
Diptera (flies)	Ceratopogonidae	19		57				
	Chaoboridae			76	192	19	134	230
	Chironomidae	134	192	115	19	19	96	
Pelecypoda (Clams)	Sphaeridae			19				
Total		229	211	419	211	38	268	230

* Taken with a 9" by 9" Ekman dredge, results in organisms/m^2.

Appendix 8

Calculation of phosphorus budget and future development options in Pencil Lake after Dillon (1975) with modifications.

A_o = 765,700 m^2
z = 8.4m.
V = $6.422 \times 10^6 m^3$
Ad = 27.35 Km

unit runoff (r) = 0.448 m/yr The mean unit runoff figure for the Eel's Creek watershed was felt to be representative of Pencil Lake conditions. Discharge records for the period 1968 to 1975 at Canada Water Survey station 02HH001, below Apsley, were used .

total annual discharge (Q) = $12.253 \times 10^6 m^3$
flushing rate (p) = 1.908 times/year

areal water load (g_s) = 16.0 m/yr

retention coefficient (R) = $\frac{13.2}{13.2+g_s}$ = 0.452

response time = 0.6 to 1.0 yr. (this indicates that any change in phosphorus loading to the lake should affect the lake water quality within about a year).

Phosphorus input from the watershed drainage

Using the revised total phosphorus export value for a forested igneous watershed (E=5.5 mg/m^2yr).

J_E (phosphorus supply from the land to the lake) =
Ad x E / 10^6 = 150.4 Kg/yr
and Le (the load) = 196.4 mg/m^2yr.

Phosphorus input from precipitation

using a revised figure for the total phosphorus loading of 50 mg/m^2yr (Dillon, 1977)

J_{PR} (phosphorus supply from the atmosphere to the lake) =
50 x $A_o/10^6$ = 38.3 Kg/yr.

Phosphorus input from cottages

For 44 cottages (the existing case) it was assumed that the phosphorus export from each cottage was 0.4 Kg/yr. This figure appears realistic for management purposes as it is below Dillon's estimated figure of 0.61 Kg/cottage which assumes that no phosphorus is retained in the septic tank and tile field and above Nicholl's (1976) figure of 0.28 Kg/cottage for cottages on Harp Lake.

J_A (the artificial phosphorus supply to the lake) =
0.4 x 44 = 17.6 Kg/yr
LA = 23.0 mg/m^2yr.
similarly development options of 33,50,75 and 100 additional cottages were calculated
the total existing phosphorus supply to the lake was
JT - 206.3 Kg/yr and LT - 264.0 mg/m^2yr
Calculation of expected water quality parameters
Using the following three equations from Dillon, spring total phosphorus concentration, mean chlorophyll a concentration and mean Secchi disc were calculated for Pencil Lake

1. $[P] = L \frac{(1-R)}{\bar{z}\ P} = 9.0\ mg/m^3$

2. $\log_{10} [Chl\ a] = 1.45 \log_{10} [P] - 1.14 \quad [Chl\ a] = 1.75 mg/m^3$

3. $\log_{10}$ S.D. = $0.717-0.41 \log_{10} [Chl\ a] \quad$ S.D. = 4.1m.

Calculations of effect of development options

for example with 33 additional cottages on Pencil Lake the additional phosphorus supply and loading is
J_{ADD} = 0.4x33=13.2 Kg/yr
LADD = 17.2 mg/m^2yr
this represents an incresed calculad [P] of

$$\frac{(264+17.2)(0.548)}{8.4X\ 1.908} = 9.6 \text{ or } 6.7\%$$

raising the measured phosphorus by the fraction the expected [P] becomes 11.2 mg/m^3
similarly the calculated [P] corresponds to a [Chl a] of 1.91 mg/m^2 or an increase of 9.14% over the estimated background concentration
Applying this percentage to the measured [Chl a] the expected [chl a] becomes 2.51 mg/m^3.

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